

Strategies in Optimizing Condensate Return

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Optimizing condensate return for reuse as boiler feedwater is often a viable means of reducing fuel costs and improving boiler system efficiency. Condensate that is contaminated with corrosive products or process chemicals, however, is ill fit for reuse; and steam or condensate that leaks from piping, valves, traps and connections cannot be recovered. According to the U.S. Department of Energy's *Steam System Opportunity Assessment for the Pulp and Paper, Chemical Manufacturing, and Petroleum Refining Industries* report (1):

- Approximately 66% could realize typical fuel savings of 3% to 7% with an effective steam trap management program
- An estimated 6.5% could realize typical fuel savings of 2.9% by minimizing vented steam
- About 24% could realize typical fuel savings of 2% by optimizing condensate return
- Around 16% could realize typical fuel savings of 1.4% by repairing steam leaks
- Approximately 7.8% could realize typical fuel savings of 0.9% by isolating steam from unused lines.

As more condensate is returned, less make-up is required, saving on both water and make-up water treatment costs. The high purity of the condensate allows for greater boiler cycles of concentration, thus reducing water and energy losses to blowdown. The high heat content (typically in excess of 180°F) can provide substantial energy savings. Additional savings will also be noted in reduced water treatment chemicals, water, and sewer costs. Effective chemical treatment, in conjunction with mechanical system improvements, condensate polishers, and automatic dump systems can assure that condensate is safely returned and valuable energy recovered.

Chemical Treatment

Corrosion in condensate systems can limit the quality or quantity of returned condensate because iron and copper corrosive products deposit on

boiler heat transfer surfaces. This reduces heat transfer efficiency and could cause tube failure.

Condensate corrosion control is required to protect process equipment, lines, and tanks, and to maintain the condensate as a quality feedwater source. Steam/condensate system corrosion can result in increased maintenance and equipment costs, energy loss through steam leaks, and loss of process heat transfer efficiency.

Condensate corrosion is most commonly associated with carbon dioxide (CO₂), although the presence of oxygen and ammonia may also be a problem. The major source of CO₂ in steam is the breakdown of feedwater bicarbonate and carbonate alkalinity in the boiler. The liberated CO₂ is carried with the steam into the condensate system.

CO₂ is not harmful until it dissolves in condensate. As it dissolves, it forms carbonic acid. Since condensate is extremely pure, even small quantities of carbonic acid can significantly lower condensate pH and increase its corrosivity. Corrosion rates increase as temperatures increase. Because condensate is hot, this causes it to be even more aggressive to metal surfaces.

Volatile neutralizing amines, such as cyclohexylamine, morpholine, and diethylaminoethanol, are typically used to neutralize carbonic acid and raise the condensate pH. These programs are most effective when fed to maintain a minimum pH of 8.5, ideally 8.8 to 9.2 (Figure 1). A blend of several amines will assure that corrosion protection is distributed throughout the entire steam/condensate system. Filming amines and a new, patented non-nitrogen based chemistry (Nalco ACT®) are alternative condensate treatments.

System Design and Maintenance

Steam/condensate system design and maintenance not only affect the delivery of quality steam, but also the ability to remove condensate from the system. Poor drainage of condensate can result in corrosion, erosion, and water hammer, all of which will eventually result in leaks and failures and limit the amount of condensate returned for reuse as boiler feedwater.

It is not within the scope of this article to thoroughly discuss all the design issues that might affect a plant's ability to return condensate.

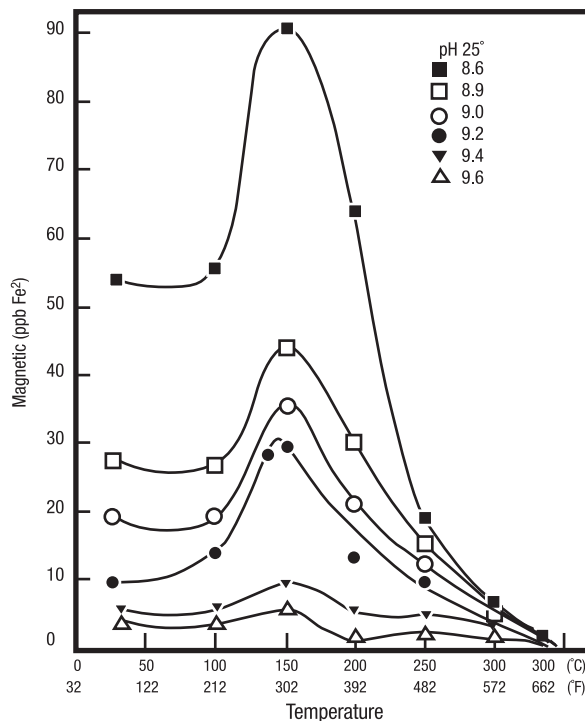


Figure 1. Solubility of magnetite in water (2).

However, common good engineering practices are listed below, as defined in DOE's *Steam System Opportunity Assessment for the Pulp and Paper, Chemical Manufacturing, and Petroleum Refining Industries* (1).

- Supply dry, high-quality steam. Steam quality must generally match process requirements and be of sufficient quality (dryness) not to erode system components. In those instances when high-moisture steam is used, a steam separator should be considered. Supply lines should also be insulated and trapped to prevent accumulation of condensate.
- Isolate steam from unused lines with properly located isolation valves. Any dead leg open to steam should be trapped to prevent condensate accumulation.
- Make sure lines and traps are properly sized. This minimizes pressure loss, erosion, heat loss, and blow-through steam. Horizontal lines should be sloped at 1 inch per 10 feet, in the direction of flow and properly supported to prevent sagging and condensate accumulation.
- Install sufficient traps on steam mains to remove condensate as quickly as possible. At a minimum, traps should be located on all vertical

risers upstream of control valves, and at 100- to 300-foot intervals along horizontal runs of pipe.

- Use the correct trap for the application. Never group trap. Group trapping invariably leads to back-up of condensate in the system.
- Ensure that piping allows the condensate to be removed effectively. Coils should be fitted with a vacuum breaker to allow condensate to drain freely. Waterlogged equipment not only fails to operate as expected, but also is prone to corrosion and water hammer.
- When possible, avoid any increase in elevation on return condensate lines. Condensate that is evacuated to a higher elevation does not flow by gravity. It requires a pressure slightly greater than the head pressure resulting from the elevation rise. When elevation of condensate after a trap is necessary, a pumping trap may be necessary to ensure good drainage.
- Install receiver vents of the proper size. Receiver vent lines that are too small restrict the loss of flash steam. This, in turn, results in hotter condensate return temperatures and potential problems with cavitation of electric condensate return pumps. Alternatively, use pressure-powered pumps.
- Make sure condensate return lines are sized to move the flash and blow-through steam present after a trap, as well as the condensate. Steam (vapor) is more voluminous than condensate (liquid). Condensate piping that is sized only for liquid is grossly undersized.
- Choose materials of construction that will minimize corrosion.

Minimizing the Effect of Contaminated Condensate

Condensate Polishers

Polishing units can be used to minimize the effect of contaminated condensate so it can be reused as boiler feedwater. A variety of polishing equipment is available for the removal of contaminants from condensate. The type of polishing equipment selected depends on the contaminant and quantity to be removed, and also on the water chemistry requirements of the boiler system.

Most polishers rely on some sort of ion-exchange technology, which replaces the contaminant with a less objectionable species. Ion-exchange units also serve as filters of suspended particulates, typically metal oxides. Simple mechanical filters with appropriate pore size, electromagnetic filters, or activated carbon filters may also be used, depending on the contaminant that is to be removed. Table 1 provides a simple comparison of some common polisher types. It is important to remember that no process is 100% efficient. However, even with a condensate polisher in line, some amount of contaminant will likely make it through to the feedwater.

Automatic Dump Systems

Another means of minimizing the effect of contaminated condensate is to sewer it before it returns or reaches the polishers. Depending on the degree of contamination, this is often a prudent action. Badly contaminated condensate may quickly exhaust or foul polishers, allowing the full amount of contamination to return to the feedwater system.

Automatic dump systems must be installed properly to be effective at detecting and sewerage condensate that is unfit for reuse. Velocities in pumped returns are commonly 6 to 8 feet per second (ft/sec) (3). Automatic control valves can take 4 to 5 seconds to actuate, close, and divert the condensate to sewer. This means there must be a minimum of 24 to 40 feet between the detection device and the valve if all contamination is to be prevented.

Most detection devices will require additional response time since they often need a cooled sample and are not located immediately on the return condensate line. Sample line size (diameter and wall thickness), length, and volume will determine how much additional response time this adds. Table 2 shows the minimum time in seconds per linear foot required for a sample to travel to the detection device. Additional time is required for the contaminant to rise to the alarm concentration. There may also be a lag time inherent in the method of analysis or detection device that must be added to the total response time.

Each of these factors increases the distance required between the detection device (or sample tap) and the automatic dump valve as shown by the following equation:

$$\text{Total distance required between valve and sample tap, in feet} = (6 \text{ to } 8 \text{ ft/sec}) \times (VR + SL + AC + MD)$$

Where:

VR = Time required for automatic dump valve to respond, in seconds

SL = Time required for contamination to travel to detection device through sample line, in seconds

AC = Time required for contaminant to rise to alarm concentration, in seconds

MD = Lag time for detection device or method, in seconds

Table 1. Comparison of Performance Data for Common Condensate Polishers

Ion Exchange	Mechanical Filters	Electromagnetic Filters
<ul style="list-style-type: none"> Flow dependent (25 to 35 gpm/ft²)* Iron leakage increases below 20 gpm/ft² 	<ul style="list-style-type: none"> Flow specific to filter, for example cellulosic pre-coat filters operate at 2 to 2.3 gpm/ft² 	<ul style="list-style-type: none"> Essentially flow independent Streams with a high percentage of magnetite may operate at 1 ft/sec
<ul style="list-style-type: none"> 80% to 90% efficient in iron and copper, or to 5 ppb** (whichever is greater) Hardness removal to 500 ppb or less 	<ul style="list-style-type: none"> 85% to 90% efficient, but only removes particulates that exceed filter pore size 	<ul style="list-style-type: none"> Preferentially removes magnetic particles Typically removes 95% of magnetite present, approximately 90% of total iron, and 50% of copper
<ul style="list-style-type: none"> Temperature limited. Some resins degrade in the presence oxygen (O₂) at temperatures as low as 100°F 		<ul style="list-style-type: none"> Operation at a pH of 9.3 to 9.5, with a reducing environment (no O₂), and relatively high temperatures is ideal
<ul style="list-style-type: none"> Prone to iron fouling 		
<ul style="list-style-type: none"> Relatively difficult regeneration 	<ul style="list-style-type: none"> Easy regeneration 	<ul style="list-style-type: none"> Easy cleaning

* gpm/ft² = gallons per minute per square foot

**ppb = parts per billion

The distance quickly becomes excessive and a failure of either the valve or detection device will still allow contamination back into the boiler system. Industrial plants with potentially nasty condensate have learned that it is much more reliable to install a redundant automatic dump system than to rely on a single system and try to get sufficient distance between sample tap and valve. The first automatic dump valve and detector should be close to the point of potential contamination. The second system can be just before the final condensate collection tank and monitor combined return streams. Be sure to consider the amount of condensate you can afford to dump (which is the amount of make-up your pre-treatment system can supply) when choosing the actual location.

If the contaminant is cationic or anionic in nature, you may be able to detect contamination by simply monitoring specific or cation conductivity. However, many particulates, suspended solids, and organics are non-ionic, and will not affect conductivity values. In those plants, an inline total organic carbon (TOC) monitor may be used to detect organic condensate contamination. Turbidimeters, particle monitors, fluorometers, and chromatographs have also had some success in detecting certain non-ionic organic contamination. Turbidimeters and particle monitors are most commonly used to detect particulates or suspended solids.

Table 2. Additional Response Time Inherent in Sample Lines

Line Size (inches)	Wall Thickness (inches)	Minimum Time (seconds per linear foot) for Contamination to Reach Detector (500 ml/min)
1/4 Tubing	0.035	0.600
	0.049	0.428
	0.065	0.267
3/8 Tubing	0.035	1.720
	0.049	1.420
	0.065	1.200
1/2 Tubing	0.035	3.430
	0.049	3.000
	0.065	2.540
	0.083	2.070

Valves should be exercised and meters calibrated to assure they are working properly. Meter measurements should be verified by grab sample at a frequency that assures the protection and reliability of the boiler system. The recommended/required frequency depends on the reliability of the meter, frequency of condensate contamination, and the effect of the contaminant on the boiler system, but should typically be done at least once per week.

Summary

Optimizing condensate return for reuse as boiler feedwater is often a viable means of reducing fuel costs and improving boiler system efficiency. Effective chemical treatment, in conjunction with mechanical system improvements, condensate polishers, and automatic dump systems can ensure that condensate is safely returned and valuable energy recovered.

References

1. U.S. Department of Energy, *Steam System Opportunity Assessment for the Pulp and Paper, Chemical Manufacturing, and Petroleum Refining Industries* DOE/GO-102002-1639, September 2002.
2. O. Jonas, "Combined Water Treatment Improves Boiler Reliability," *Power*, April 1984.
3. Spirax Sarco, Inc., SC, *Hook-Ups, Design of Fluid Systems*, 2000.